

HOW IT WORKS

Hybrid hard disks and Turbo Memory

Microsoft and Intel claim to have developed new ways of using flash memory that will boost computer battery life and save power. Others, however, are sceptical about the benefits of this technology. Tom Royal investigates

In our May 2007 issue we explained how several key technologies in Windows Vista are designed to improve performance using clever memory paging and flash memory. This month we'll explain how new hardware devices have sprung up to make use of these Vista technologies, and how they could help notebook computers run for longer on battery power.

In particular we'll look at hybrid hard disks, which combine a standard hard disk with flash memory, and Intel's Turbo Memory, which puts a specialised flash memory cache on a notebook motherboard.

MIX AND MATCH

We previously explained how Windows Vista's ReadyBoost feature allows you to use a flash memory drive as virtual memory. In future, though, many notebook computers running Windows Vista are likely to perform a similar trick without you plugging in any extra devices. A hybrid hard disk, or H-HDD, mixes hard disk and flash memory technology. When used with appropriate software, a hybrid disk can help computers to boot and resume from hibernate faster, and to conserve power.

All modern hard disks include a cache of fast DRAM memory. This allows them to perform certain operations faster than would be otherwise possible. For example, when a computer writes several megabytes of small files to the disk, the disk can transfer them to its cache memory almost immediately, and store them there while writing them to the actual hard disk platter. This makes the transfer from the computer to the hard disk far faster than it would be if the computer had to spin up the hard disk and write each file to different locations one at a time.

Hybrid hard disks retain this cache memory, but add a second cache of flash memory. Flash memory is slower than the DRAM memory used for a standard hard disk cache, but it has the significant advantage of being non-volatile. This means that, just as a thumb drive retains the data stored on it when you unplug it from a computer, any data stored in the flash memory cache will remain there if the computer is switched off or put in hibernate mode.

Windows Vista includes a new feature called ReadyDrive that allows it to use the flash memory cache in a hybrid hard disk to reduce the time taken for computers to start up. It can do this because most modern computers are capable of processing the files needed to start

Windows more quickly than they can be transferred from the hard disk. When shutting down, a computer with ReadyDrive and a hybrid disk copies files that will be needed to start up again to the flash memory of the hybrid hard disk. When the computer is restarted, these files can be read very quickly from the flash memory while the hard disk is still spinning up. This has the potential to cut the time needed to start the system significantly. A similar technique can be used when returning from hibernate mode.

Microsoft and the manufacturers of hybrid disk drives have also been keen to publicise the possible benefits of fitting hybrid disks into notebook computers. They quote two advantages: extended battery life, and less risk of hard disk damage. Both rely on the principle of switching off the physical hard disk whenever possible.

MEMORY GO ROUND

In order to shut down the hard disk without a significant impact on performance, Windows Vista uses its SuperFetch technology to predict the data that's likely to be needed based on previous usage. This is then loaded into the main system memory, ready for use, and the system instructs the hard disk to stop spinning. For more information on SuperFetch, see *How it Works: Windows Vista*, *Shopper* May 2007.

If SuperFetch has done its job well, any data needed by the running applications should be in memory already, so the disk won't need to start spinning again for some time. In the meantime, if any data needs to be written to the disk it is instead written to the flash memory cache inside the hybrid drive.

The system keeps running with the disk stopped until one of two events occurs. If the flash memory cache fills up, the hard disk must be spun up so that all the data stored in flash can be copied across to the disk itself. With this done the disk stops spinning and the flash memory is cleared so more data can be cached.

Alternatively, the system might request data that hasn't been paged into memory by SuperFetch. This could happen if you do something unpredictable, such as opening a DVD player application in the middle of your normal working day. In this case the hard disk will have to start up as normal to read the data, then stop again.

With the hard disk at a standstill the computer uses less power, so if a notebook computer with a hybrid disk can keep its hard

disk stopped most of the time, it should use less power and run for longer on one battery charge. What's more, keeping the hard disk at a standstill whenever possible also decreases the possibility of it becoming damaged if the computer takes a knock. The hard disk is easily damaged if it is subjected to force while the read and write head is located over the disk surface, but when the disk is stopped the head is moved to one side where it's far less likely to whip against the disk and cause harm. Many more expensive notebooks already incorporate sensors that stop the hard disk when they notice a sudden acceleration or shock. If a hybrid hard disk can stay stopped most of the time, with the head parked safely to one side of the disk platter, knocks or bumps are less likely to cause damage.

READY TO ROLL

ReadyDrive technology is included in every edition of Windows Vista, and the first hybrid hard disks are beginning to appear on the market. Samsung's SpinPoint MH80 HM08HHI is an 80GB notebook hard disk fitted with 8MB of standard buffer memory and 256MB of flash memory.

Shopper is yet to review a notebook with a hybrid hard disk, however, and critics have pointed to several potential drawbacks that could limit the usefulness of the technology. One of the most obvious is the speed at which non-paged data can be retrieved. If a hybrid disk is spun down and the operating system requires data that has not been loaded, or 'paged', into memory, the computer will need to spin the disk

FURTHER INFORMATION

Microsoft presentation on hybrid disks from WinHEC 2006:

www.microsoft.com/whdc/system/sysperf/accelerator.mspx

Toshiba document with technical details on NAND flash:

www.dataio.com/pdf/NAND/Toshiba/NandDesignGuide.pdf.pdf

EWeek article questioning the reliability of flash memory in hybrid disks:

www.eweek.com/article2/0,1895,1975101,00.asp

Intel demonstration of Turbo Memory technology (codename Robson):

www.intel.com/technology/magazine/computing/robson-1206.htm

up before it can retrieve it. Spinning up a hard disk takes time, so this will introduce a noticeable delay. By contrast, in an ordinary computer, where the hard disk is spinning more often, there's a higher chance that the hard disk will already be spinning. This will allow it to retrieve non-paged data more quickly.

Similarly, hybrid disk systems are likely to spin up the disk from a standstill more often than normal disks. Hard disks use more power when spinning up than when running constantly, so some have suggested that the power savings offered by hybrid disks might not be that great.

Some have also raised concerns over the durability of the flash memory used inside a hybrid disk. Flash memory has a limited lifespan, and a Toshiba document quotes the endurance of NAND flash as being "more than 100,000 to 1,000,000" reprogrammings. This means that the flash memory cache of a hybrid disk could possibly fail before the physical hard disk itself, as Toshiba has stated that "it is estimated that at least 1,000,000 cycles are required to replace a hard disk drive".

Since hard disks already include technology to identify and avoid the use of damaged parts of the physical disk, though, it should be possible to use a similar system to limit the harm caused by failing flash memory cells. It's also possible to evenly distribute data between memory cells so that no one cell is overly burdened, using a process that's known as wear levelling.

ROBSON'S CHOICE

While hard disk manufacturers have been developing hybrid hard disks, Intel has been pursuing a similar technology. Originally known by the code name Robson, Intel's Turbo Memory technology was unveiled this year as part of its new Santa Rosa mobile chipset. It uses a PCI Express mini card, connected to the notebook motherboard, that holds two flash memory chips and a controller. The flash memory chips hold either 256MB or 512MB of data each, giving the card a total of 512MB or 1GB of memory depending on its configuration. The memory is split between two Windows Vista functions.

Part of the memory on a Turbo Memory card is used with Windows Vista ReadyDrive to perform the same role as the flash memory in a hybrid hard disk. The rest of the memory is used as a ReadyBoost page file. We explained ReadyBoost in detail in *How it Works: Windows Vista*, *Shopper* May 2007. In short, it uses flash memory to store a special page file. This is used for paging small, non-sequential chunks of data, as flash memory is much faster when manipulating this kind of information than a standard hard disk. When manipulating larger items, the standard page file stored on the computer's hard disk is used instead.

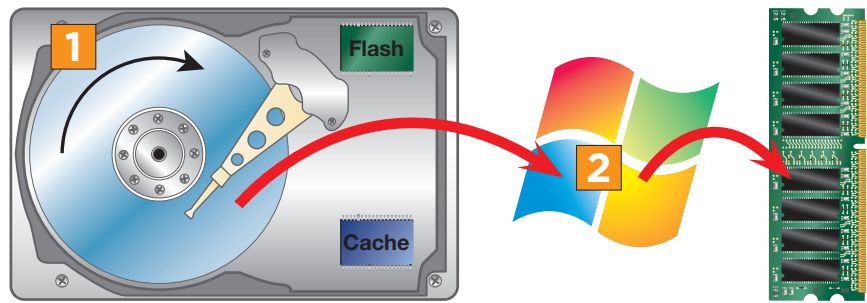
Turbo Memory has the potential to provide battery life gains similar to those of a hybrid hard disk, but it's subject to similar drawbacks. It too requires the use of flash memory that has a limited life cycle, although as with the memory in a hybrid disk, wear levelling could extend its lifespan significantly. It's also possible to incorporate spare memory cells that are only used once others have failed.

MEMORY LAME

Interestingly, although Santa Rosa notebooks have been available for a while now, *Computer Shopper* is yet to review one with a Turbo

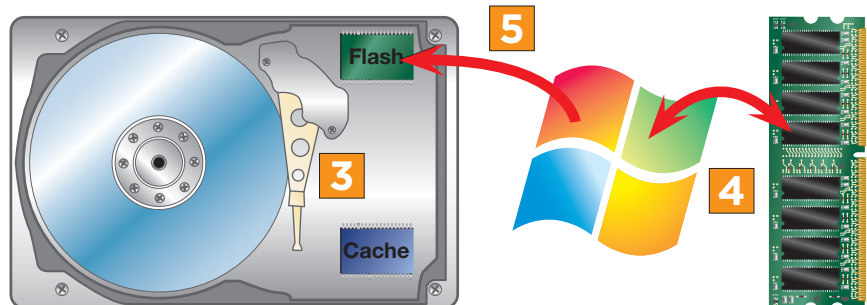
Power down How hybrid hard disks save energy

SUPERFETCH PAGES DATA



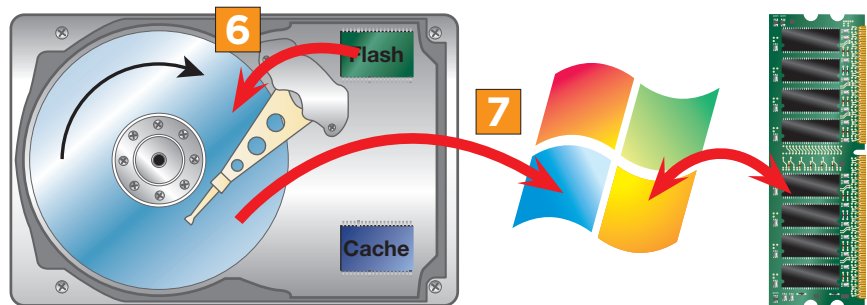
▲ Hybrid hard disks contain a large cache of flash memory as well as a disk and a standard memory cache. The hard disk spins up as usual (1), then Windows Vista's SuperFetch technology pages data that it thinks is likely to be needed into the system memory (2). SuperFetch analyses your computer usage to increase the accuracy of its predictions

THE DISK SPINS DOWN



▲ Once SuperFetch has finished paging into the main memory, the hard disk itself can be spun down (3) and the head parked. This saves power, and makes the disk less vulnerable to shocks. If Windows needs to read any data, it should be located in the main memory (4). If Windows needs to write to the disk, it stores this data in the flash memory instead (5).

THE DISK SPINS UP AGAIN



▲ Two events can cause the disk to spin up again. If the flash memory fills up, the disk must be started so that the data in flash memory can be copied to it (6). Alternatively, if Windows requests some data that has not been paged to the system memory, then the disk must be started to read this data (7).

Memory card fitted. In fact, several major notebook manufacturers have been surprisingly critical of the technology. HP has stated that it won't add Turbo Memory to any of its Centrino Pro notebooks. HP's Steve Doddridge told the technology website ZDNet that HP had evaluated the technology, but found that adding more physical memory to the test notebook produced a "much higher improvement in performance compared to using any of the ReadyBoost or Robson technology". He also cited the fact that notebooks using Turbo

Memory cannot be further expanded by using a USB flash drive for ReadyBoost.

Similarly, in June 2007, Sony's David Spaeth announced that the company's summer 2007 range would not include Turbo Memory. He also claimed that Windows Vista would not be able to take full advantage of Turbo Memory until the release of the first Service Pack, although this claim was contested by Microsoft.

Shopper will, of course, fully examine the benefits of both hybrid disks and Turbo Memory as soon as products become available. ☐